CHAPTER 5 – BARRIERS

5.1 Introduction

Levees and floodwalls are types of flood protection barriers. A levee is typically a compacted earthen structure; a floodwall is an engineered structure usually built of concrete, masonry, or a combination of both (Figure 5-1). Barriers can be built to protect a single structure or multiple structures as regional facilities.

CAUTION

Levees and floodwalls may not be used to bring a substantially damaged or substantially improved structure into compliance with the community's floodplain management ordinance or law.

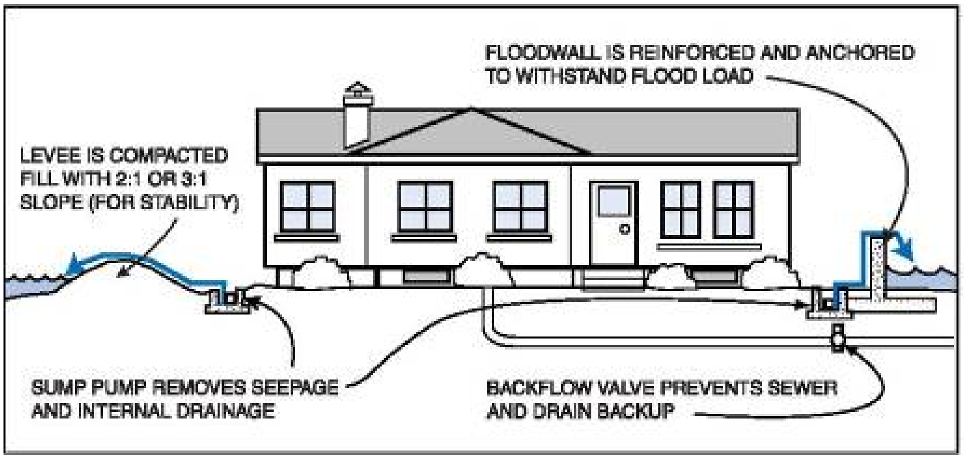

Figure 5-1. Structure protected by levee (on left) and floodwall (on right)

(Source: FEMA 312)

Table 5-1 includes a summary of advantages and disadvantages for using barriers as a mitigation measure.

Table 5-1. Considerations for Using Barriers

Advantages	Disadvantages
▪ Floodwaters cannot reach the structure(s) in the protected area and therefore will not cause damage through inundation, hydrodynamic pressure, erosion, scour, or debris impact. ▪ The structure and the area around it will be protected from inundation, and no significant changes to the structure will be required.	▪ Barriers may not be used to bring a substantially damaged or substantially improved structure into compliance with the community's floodplain management ordinance or law. ▪ Cost may be prohibitive, as a large area may be required for construction. ▪ Periodic maintenance is required. ▪ Local drainage can be affected, possibly creating or worsening flood problems for others.

Types of barriers include levees, berms, floodwalls, and temporary barriers.

5.1.1 Levees

Levees are embankments or structures constructed of compacted earthen materials and differ from berms in size. Construction of a levee begins with excavating and inspecting the cutoff trench. Its initial purpose is to give the designer a better look at the subsurface soil conditions, so that the presence of roots, utility lines, and animal burrows, or changes in soil conditions are considered during the design process. The interior of the levee is composed of an impermeable core, usually clay. The lifts of impervious clay fill are placed in 6-inch layers and with each lift being compacted to the density specified by the designer of the levee (Figure 5-2). Like large floodwalls, levee design should be accomplished by a licensed engineer.

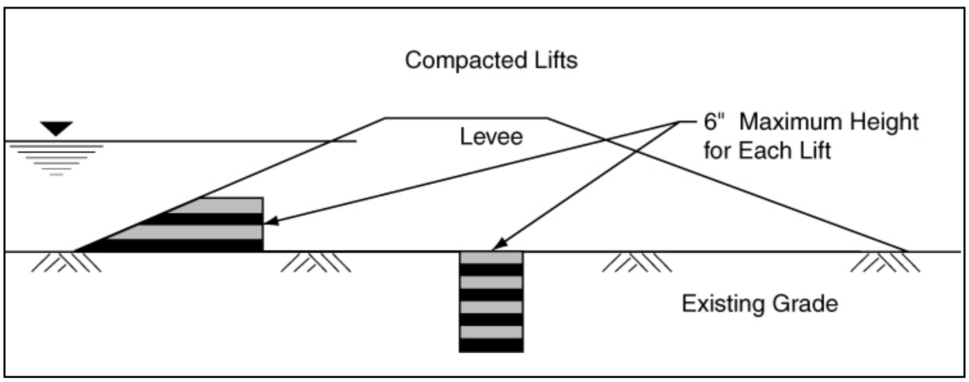

Figure 5-2. Levee construction

(Source: FEMA 259)

5.1.2 Berms

Berms can be utilized to completely encircle a building. However, they require a lot of room and a large quantity of earthen fill. Unless the fill is readily available nearby, hauling it to the site may prove to be cost-prohibitive. One way to decrease this expenditure is to incorporate the berm into existing high ground.

5.1.3 Floodwalls

A floodwall is an engineered structure made of reinforced concrete or reinforced concrete block and varies anywhere from 1 foot to over 20 feet in height. A floodwall can surround a structure or, depending on flood depths, site topography, and design preferences, can protect isolated openings such as doors, windows, and basement entrances, including entry doors and garage doors. When built with decorative bricks or blocks or as part of garden areas, floodwalls can become attractive architectural or landscaping features. But they can also be built solely for utility, usually at a much lower cost.

Since a floodwall is made of concrete or masonry rather than compacted earth, it is more resistant to erosion than a levee and requires less space than a levee that provides the same level of protection. But floodwalls are often more expensive. As a result, floodwalls are normally considered only for sites where there is not enough room for a levee or where high flow velocities may erode a levee. Also, some property owners prefer floodwalls because they can be more aesthetically pleasing and allow for the preservation of existing site features, such as landscaping and trees (Figure 5-3).

Figure 5-3. Structure protected by a floodwall with landscaping features

5.1.4 Temporary Barriers

There are several types of temporary barriers available to address many of the flooding problems typically encountered. They work with the same principles as permanent barriers such as floodwalls or levees, but can be removed, stored, and reused in subsequent flood events. Most of these barriers are meant to take the place of sandbag floodwalls and may also be used to reinforce existing permanent barriers such as levees or berms (Figures 5-4 and 5-5).

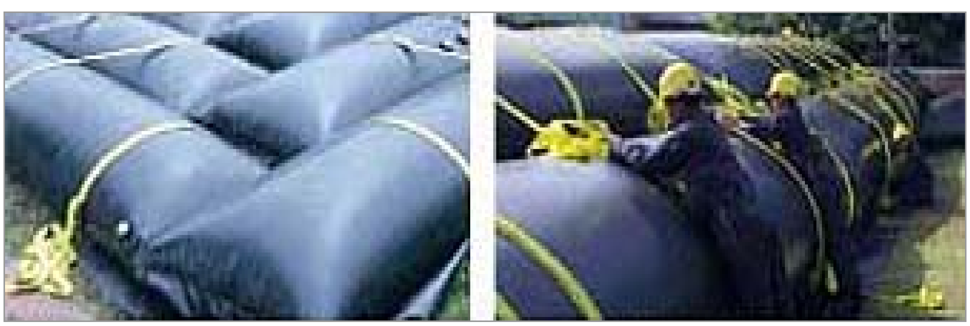

Figure 5-4. Water-filled temporary barriers deployed and anchored in place. Installation designed for a 3-tiered placement, protecting to approximately 7 feet in depth.

(Source: FloodMaster Barriers, Inc.)

Figure 5-5. Metal supports for floodwall installed for deployment. Floodwall deployed with impermeable membrane.

(Source: FloodMaster Barriers, Inc.)

These products are designed so that they can be utilized numerous times. Additionally, a joint program between the Federal Government and an internationally recognized certification laboratory will begin in the fall of 2006 to test and certify temporary, emergency measures for flood protection products.

5.2 Technical Considerations

5.2.1 Height of Barrier

When barriers are built to protect a single structure, they are referred to as “residential,” “individual,” “on-site,” or “local” levees and floodwalls. The practical, cost-effective heights of these levees and floodwalls are usually limited to 6 feet and 4 feet, respectively. These limits are the result of the following considerations:

- The higher the levee or floodwall, the greater the depth of water that builds behind it and the greater the water pressure exerted on the barrier. Levees and floodwalls must be designed and constructed to withstand the increased pressures. Meeting this need for additional strength greatly increases the cost of the levee or floodwall, usually beyond what an individual property owner can afford.
- Because taller levees and floodwalls must be stronger, they must also be more massive, so they usually require more space than is likely to be available on an individual lot. This is especially true of levees.
- Local zoning and building codes may also restrict use, size, and location.

If the flood depth at the project site is above the practical height limits, an alternative mitigation method, such as elevation, should be considered. The levee or floodwall can always be overtopped by a flood higher than expected regardless of the height of the barrier. Overtopping is a greater concern for a levee than a floodwall since a small amount of overtopping can cause erosion at the top of the levee and cause it to fail.

5.2.2 Structure with Basement Foundation

Special design considerations are necessary when levees or floodwalls are built to protect a structure with a basement. Even though the surface water is kept from coming into contact with the structure, the soil below the levee or floodwall and around the structure can become saturated, especially during floods of long duration. The resulting pressure on basement walls and floors can cause them to crack, buckle, or even collapse. An analysis by a qualified soils engineer can help locate a floodwall or barrier a sufficient distance from the structure to lessen or alleviate this pressure.

5.2.3 Soil Conditions

The type of soils encountered may have a significant impact on the choice of barriers as a flood protection option. This is true regardless of whether the choice is a permanent barrier or a temporary barrier. The following soil-related considerations must be taken into account:

- **Bearing capacity.** All of the permanent barriers and many of the temporary barriers are very heavy. If the soil is of the type that has low bearing capacity characteristics, the barrier may either fail structurally or begin to sink, losing its design protection height.
- **Permeability.** Barriers will ideally be deployed on tight, impermeable soils. If the soils are permeable, such as sand or sandy loam, geotechnical steps will need to be taken to counteract the seepage of water under or through the barriers. This may include an impervious core to a levee or a deeper cut-off trench filled with impermeable clay soil.

5.2.4 Duration of Flooding

Eventually, all barriers will have seepage or leakage through the barrier if they are exposed to floodwaters for an extended period of time. If the duration of flooding is relatively short (less than 1 day) and depth of flooding is relatively low (less than 1 foot), many barriers will at least slow down the effects of inundation. Longer exposure will require barriers that are better engineered and more carefully constructed or deployed. Likewise, deeper flood depths will also need to be considered due to the extremely high forces exerted on the barriers by the weight of the floodwaters.

5.3 Relative Costs

The relative cost ranking is based on the combination of the estimated costs for the barrier project and a determination of cost-effectiveness.

5.3.1 Estimated Cost

The costs for a barrier project, such as floodwalls and levees, are generally inexpensive. The costs for levee construction can vary greatly, depending on the distance between the construction site and the source of the fill dirt used to build the levee. The greater the distance that fill dirt must be hauled, the greater the cost.

Examples of cost estimating items that may need to be considered include the following:

- Field investigation to collect data and to develop a plan of action
- Design of the barrier
- Design of the drainage systems
- Design for architecture details
- Construction

To estimate the relative cost of a barrier project, examples of general cost estimates have been provided below and are included in FEMA 312, *Homeowner's Guide to Retrofitting: Six Ways to Protect Your House From Flooding* and FEMA 259, *Engineering Principles and Practices of Retrofitting Floodprone Residential Structures*.

The figures in Table 5-2 are example cost estimate numbers developed for a study for the St. Louis Metropolitan Sewer District. These numbers were generated using the U.S. Army Corps of Engineers' publication, *Flood Proofing - How to Evaluate Your Options*, and updated to 2002 and adjusted for the St. Louis area. It is important to note that the cost estimate numbers are location and time dependent.

Table 5-2. General Estimates of the Unit Costs for Typical Barrier Projects

Levee/Berm	
2 feet above ground	$60/linear foot
4 feet above ground	$106/ linear foot
6 feet above ground	$170/ linear foot
Floodwalls	
2 feet above ground	$92/linear foot
4 feet above ground	$140/linear foot
6 feet above ground	$195/linear foot

Appendix C, Cost Estimating, provides guidance and references for conducting a more detailed cost estimate. Additional cost estimates can be obtained from R.S. Means' *Contractor's Pricing Guide*. A blank preliminary cost estimating worksheet (Worksheet D) is provided in Appendix B.

5.3.2 Determination of Cost-Effectiveness

A component of the relative cost scoring is to include a determination of cost-effectiveness. Table D-1 in Appendix D, Determining Cost-Effectiveness, provides a quick screening for the cost-effectiveness of a project. The attributes included in the table are frequency of flood, level of damage, project cost, project benefits, and criticality (impact or loss of function). For example, if the frequency is the 10-year flood, the project will have a very high likelihood of cost-effectiveness.

Based on the combination of the estimated cost of the project and the likelihood of cost-effectiveness, a relative cost ranking will be assigned on Worksheet B, Appropriate Mitigation Measures. If the likelihood of cost-effectiveness is low, the ranking of relative cost will be either moderate or high, based on the estimated cost of the project. However, if the estimated cost is low and the likelihood of cost-effectiveness is very high or high, the relative cost ranking will be low.

5.4 Additional Considerations

5.4.1 Human Intervention

As described in Section 5.4.4, openings in the barrier will need to be closed prior to a flood event. Putting the closure mechanisms in place require human intervention. The barrier will not protect the structure from flooding unless the property owner is willing and able to operate all closures before the floodwaters arrive.

5.4.2 Annual Maintenance

A barrier requires periodic inspections and maintenance to address any necessary repairs. Otherwise, small problems, such as cracks, loss of vegetation, and erosion and scour, can quickly become large problems during a flood event. The barrier should be inspected at a minimum each spring and fall, before each impending flood, and after each flood event. To facilitate maintenance and the mowing of grass, the side slopes of most berms should not be steeper than 1-foot vertically to 4-feet horizontally. A driveway should probably not be steeper than a 1 to 3 slope. Trees and large shrubs should not be located on barriers. When they die, their roots decay, leaving routes for water to pass through, causing the barrier to fail.

5.4.3 Housing of Occupants

Although the building can be used during construction of the barrier, the building should not be occupied during a flood event. Levees and floodwalls may give the property owner a false sense of security. Every flood is different and the one that exceeds the height of the barrier could occur at any time. If water overtops the barrier, the protected area will fill rapidly and evacuation should occur well before this happens.

5.4.4 Access to Structure

Access to the structure may be difficult. Openings will need to be created or provided for driveways, sidewalks, and other entrances. These openings must be closed prior to the flood event occurring, as floodwaters can rise rapidly enough to prevent an opening from being closed. Examples of these closure mechanisms for floodwalls include shields similar to the ones used in dry floodproofing or prefabricated panels and permanently mounted, hinged, or sliding flood gates and prefabricated stop logs or panels for levee openings. Unless the gates remain in the closed position at all times, human intervention is required to close an entry point to prevent rising floodwaters from entering the structure (Figure 5-6).

Figure 5-6. The City of Boulder, Colorado, installed a “pop up” closure to this floodwall at a City office building subject to flash floods. The closure floats up into place automatically when the site is flooded.

5.4.5 Interior Drainage

Interior drainage must be taken into account and provided for since building a barrier that keeps floodwater out of the protected area also will keep water in. Drains and sump pumps should be installed to remove water collected inside the barrier. In addition, caution must be taken to ensure that local drainage patterns in the area are not disrupted. As shown in Figure 5-7, an interior drainage system, including a sump pump, must be installed in the area protected by a levee or floodwall.

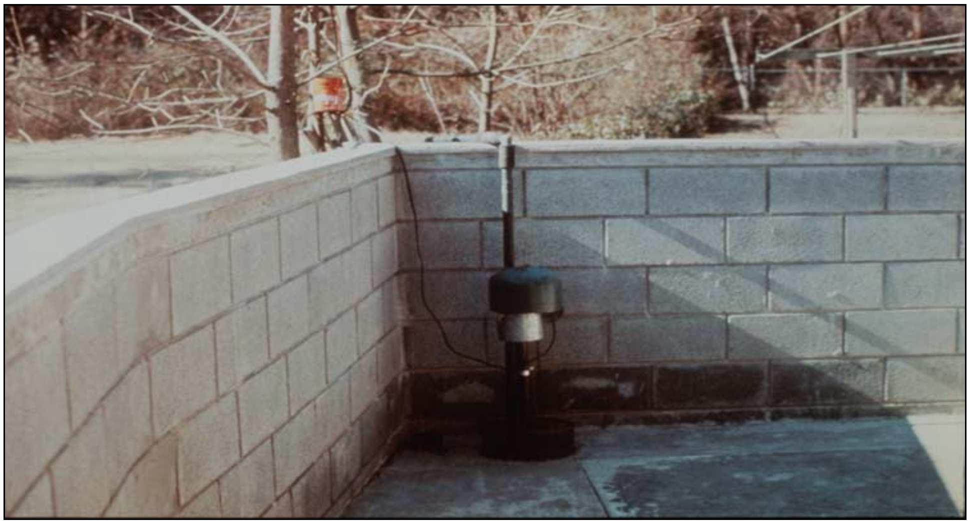

Figure 5-7. Small patio floodwall with sump pump

5.5 Available Resources

FEMA 259. *Engineering Principles and Practices of Retrofitting Floodprone Residential Structures.* See Chapters VI-F, Floodwalls and VI-L: Levees.

FEMA 312. *Homeowner's Guide to Retrofitting: Six Ways to Protect Your House from Flooding.* See Chapter 3, An Overview of the Retrofitting Methods and Chapter 7, Other Methods – Levees and Floodwalls.

FEMA 511. *Reducing Damage from Localized Flooding*. See Chapter 10, Retrofitting.

The Louisiana State University (LSU) Extension Center website (http://www.louisianafloods.org) lists many retrofitting publications, provides advice on floodproofing methods and flood insurance, and links to online shopping for retrofitting products and contractors.

USACE. *Flood Proofing - How to Evaluate Your Options.*

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